

U.S. Mines Bureau

Bulletin 4

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

JOSEPH A. HOLMES, DIRECTOR

FEATURES OF

PRODUCER-GAS POWER-PLANT
DEVELOPMENT IN EUROPE

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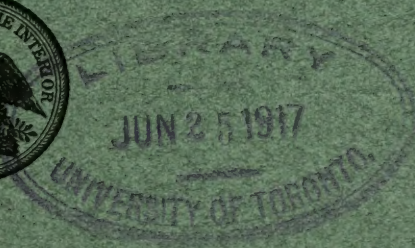
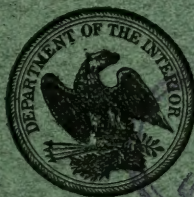
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BY

R. H. FERNALD

ENGINEERING

ENGINE STORAGE



WASHINGTON

GOVERNMENT PRINTING OFFICE

1911

1955

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OF THE POWER-PLANT

INDUSTRY IN EUROPE

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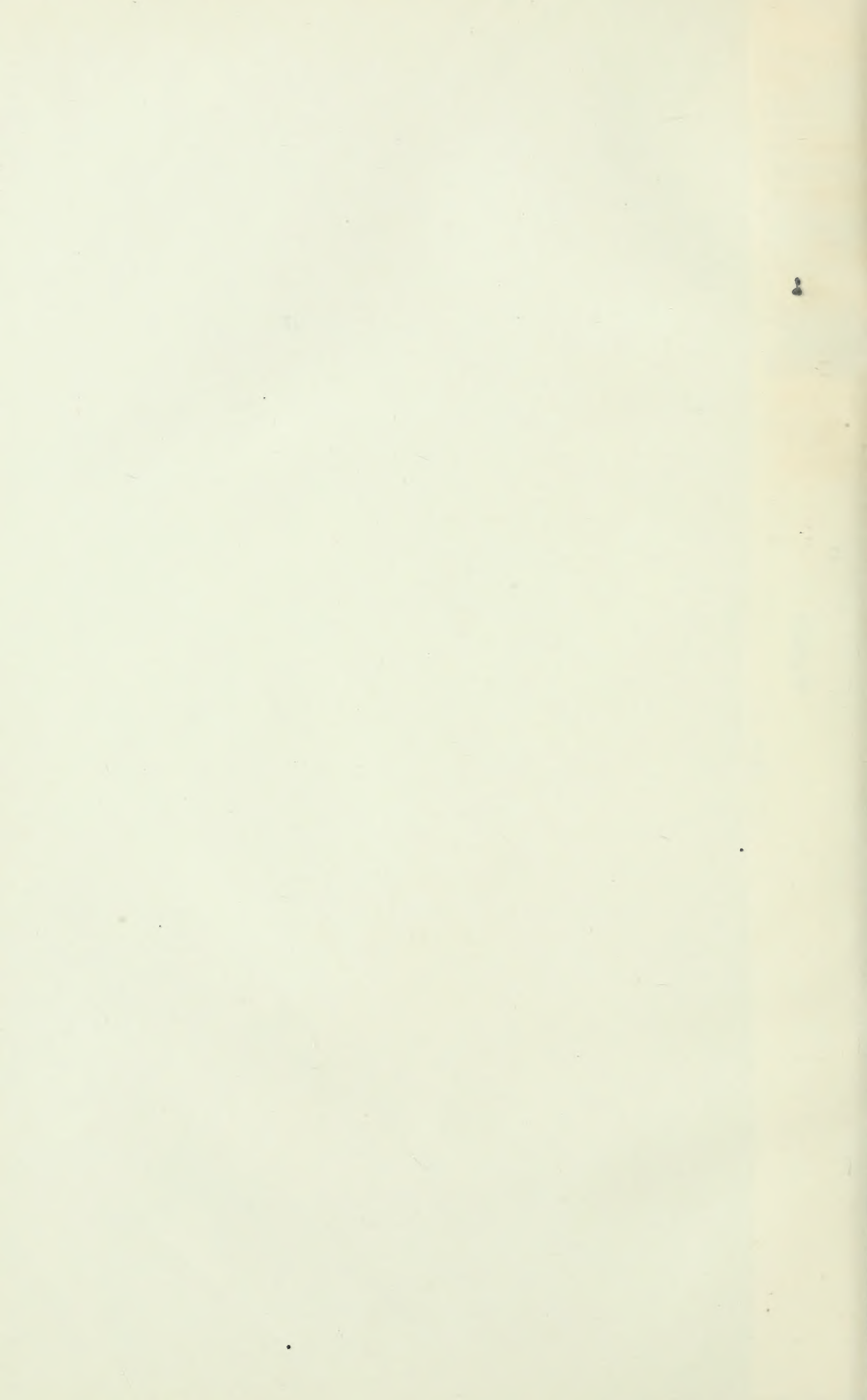
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INDUSTRY



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FEATURES OF PRODUCER-GAS POWER-PLANT DEVELOPMENT IN EUROPE.

By ROBERT HEYWOOD FERNALD.

INTRODUCTION.

The analyzing and testing of mineral fuels as carried on by the United States Geological Survey included trials of coal, lignite, and peat in a gas producer. These tests were made in connection with steaming and other tests, the object of the investigation being to find out in what ways the mineral fuels in the United States could be utilized most efficiently, and by what means deposits of low-grade fuel that were lying undeveloped or were being wasted could be made of immediate or prospective importance as assets of the nation's mineral wealth.

The tests of fuels for producer-gas manufacture began in 1904 and were continued by the United States Geological Survey up to July 1, 1910, on which date all of the fuel-testing work being carried on by the Survey was transferred by act of Congress to the Bureau of Mines. Results of some of the producer-gas tests made before that date have been given in the Geological Survey publications listed at the end of this report; results of other tests will be given in bulletins to be issued by the Bureau of Mines.

In the course of its investigations the Geological Survey collected information relating to the development of producer-gas power plants in the United States, giving particular attention to the fuels used, the efficiencies obtained, and the operating troubles or other drawbacks reported by owners. To get further particulars regarding the possibility of utilizing fuels undeveloped or wasted, the writer was authorized to visit those European countries where gas producers and gas engines are more widely used than in the United States and to inspect those plants which had been most successful in utilizing poor fuels. The writer made this trip of inspection in the fall of 1908 and visited plants in ten countries during a two-month journey.

Because the limited time available would not permit a careful inspection, much less a detailed study of all the plants visited, the writer has not aimed in this bulletin to present a comprehensive review of producer-gas power-plant development in Europe, or even to give such conclusions as might be drawn from what he saw, but has simply described some interesting features of European practice that attract the attention of even a casual observer. Inasmuch as his journey

was made with the special purpose of studying the utilization of low-grade fuels, only passing attention was given to producer plants of standard types using anthracite or other high-grade fuel. For that reason, and also for the reason that the reliability of producers running on anthracite is well established, this report merely outlines certain important features of European practice with suction producers using anthracite or coke.

The writer takes this opportunity to acknowledge the courtesies shown him at the plants he visited, and to thank most cordially the many persons who in one way or another aided him to obtain the information he sought.

USE OF ANTHRACITE OR COKE.

Suction producers fed with anthracite or coke are in general use at small power plants in Great Britain and on the Continent. They seem to give satisfaction, although their operating cost is apparently somewhat greater than the figures stated by the manufacturers. The number of producer-gas power plants in England has become so large that it is said to have caused an advance in the price of anthracite. In one city I was told that the price of a grade of anthracite had been \$4.85 a ton before the introduction of gas-producer plants, but had risen to \$7.25 since.

Coke is used abroad much more generally than in this country. Many users say that it gives best results when it is crushed to walnut size. Some English power-plant owners, to reduce fuel bills, used a mixture of the two fuels (coke and anthracite) in their producers, as the price of coke in 1908 was about \$3.75 a ton.

A manufacturer of a suction plant in general use advertises "20 h. p. hours for 1d." on coke. The writer investigated one of these plants and was informed by the owner that although coke cost him only about one-half as much as anthracite he was obliged to use twice as much, so that the expense for fuel was practically the same whichever fuel he used. Under average conditions the fuel cost of power was 1 penny for about 9 horsepower-hours. Under the best conditions the plant might develop 12 or 14 horsepower-hours on 1 penny's worth of fuel, but would not develop 20 horsepower-hours on that quantity.

In Belgium the anthracite generally used in suction plants seems to give entire satisfaction. At some plants it was reported that the anthracite contained 6 to 8 per cent ash, practically no sulphur, and little tar. The coal shows little tendency to cake, and its average heat value is 13,500 B. t. u. per pound. It costs \$3 to \$4 per ton at the mine.

In Germany gas producers of both the suction and pressure types burn anthracite, and all kinds and sizes of gas engines are built to run on producer gas. In 1908 one company was turning out 400 engines a month, most of which were to use this gas.

Small producer-gas plants of the suction type that used good anthracite were reported to require from 0.7 to 1 pound of water for the vaporizer and from 10 to 15 pounds of scrubber water for each pound of coal fired.

One practice of some of the engine manufacturers in Europe that deserves commendation is not to overrate their engines. For example, many engines rated at 50 will show 60 brake horsepower continuously under test, and those rated at 35 to 40 will show 50 horsepower. This gives an overload capacity of apparently 20 to 30 per cent.

Some of the companies that formerly made all their producer-gas engines of the hit-and-miss type now make all their large ones of the constant-mixture, throttled type.

Some manufacturers showed suction-type producer outfits especially designed for burning anthracite screenings. These outfits seemed to be of serviceable design and construction, but the author saw none in operation outside of the works of the various manufacturers.

PLANT AT SCHEVENINGEN, HOLLAND.

One of the most interesting of the suction-type plants burning anthracite which were visited is the central lighting plant at Scheveningen, Holland. The details of this are noted below:

Number of producers: 6.

Type of producers: Suction.

Rated capacity of producers: 350 horsepower each.

Number of engines: 5.

Make of engines: Nürnberg.

Type of engines: Horizontal, double-acting, tandem, direct connected to 235-kw. generators.

Rated capacity of engines: 350 horsepower each.

Engines in operation: 1 by day, 4 at night.

Use of power: Lighting city.

Service hours a day: Twenty-four hours for one engine; variable number at night for the others.

Number of men required: At night, 1 in producer room, 3 in engine room, and 1 at switchboard.

Fuel used: Selected lump anthracite; 4, 6, and 8 inch lumps.

The scrubbers contain wooden slats and a water spray.

A special tar extractor used consists of iron plates full of small holes. These plates revolve slowly and dip in a warmed hydrocarbon oil that dissolves the tar.

Large purifiers containing iron oxide and shavings are used for removing the sulphur.

An exhauster draws the waste gases from the engines and forces them into a chimney, thus reducing the back pressure on the engines.

A particularly important feature of the plant is the setting of the engines in such manner that all parts are easily accessible.

At the time of the writer's visit in 1908 this plant had been in operation four and one-half years and had given excellent service.

USE OF BITUMINOUS COAL.

At the large producer-gas power plants in Europe bituminous coal is generally used, both at those which save by-products and at those which do not. With one or two notable exceptions, however, there seems to be no attempt to utilize low-grade fuels. In fact, the coals burned in power-gas producers are apparently especially selected for such use. Most of the manufacturers state that they confine their attention to making producers for short-flaming coals that are low in ash and in tar and do not cake, although one manufacturer claims his producers give no trouble with high-ash fuels and believes he can run them on coal containing an extremely high ash content, provided the coal is not a caking variety.

The cost of average grades of bituminous coal in one section of England is given as \$2.25 per ton and in Sweden as about \$3.75.

PLANT AT A TOWN IN WALES.

At an installation in Wales of the by-product type, which comprises two pressure-producer units of 1,250 horsepower each, the engineer stated that the coal used contained 23 per cent ash, 27 per cent volatile matter, and 2 to 3 per cent sulphur. In 1908, when one-half of this plant was in operation, none of the sulphur was removed from the gas. At this plant the producers have asbestos jackets, and the engineer claimed that these jackets increased the efficiency 5 per cent. Some of the details of this plant are as follows:

Number of producers: 2. (Only one in use at time of visit, the second having just been erected.)

Make of producers: Crossley.

Type of producers: Pressure.

Rated capacity of producers: (10 feet in diameter) 1,250 horsepower each.

Number of engines: 4.

Make of engines: Crossley.

Type of engines: Horizontal, two-cylinder, opposed, single-acting.

Rated capacity of engines: 350 horsepower each.

Load carried: 350 horsepower at the time of my visit.

Use of power: Electric power about works; gas also used for heating purposes.

Number of men required: Engineer in charge, 2 men on the producers and 1 in the engine room, each shift, when running full load.

Methods of charging producers: At full load the fuel is charged and the fuel bed poked about every hour, but at times every forty-five minutes.

Kind of fuel: Bituminous coal reported to contain 23 per cent ash and 27 per cent volatile matter.

The producers operate on the Taylor principle. Between the gas generator and the economizer is a baffle box that prevents dust and other impurities from passing into and clogging the economizer pipe. The economizer and the coke scrubbers are of the design usually made for such producers, and the tar extractor is of the centrifugal type. The tar thrown out by the extractor proves a valuable by-product, as indicated on page 12.

The process of cleaning the gas and some other features of the plant are especially interesting. The gas after passing through the tar extractor goes to a sawdust scrubber, which removes tar and dust as well as moisture. There are two of these sawdust scrubbers, either of which can be by-passed and run independently to facilitate the cleaning of the other.

No gas tank is used. A small holder, about 30 inches in diameter, is connected to the gas pipe supplying the engine and to an electric resistance switch which controls the motor for the Root blower that gives the blast for the gas generator. When the pressure in the gas main decreases the holder falls, pulls the switch, and speeds up the blower.

The necessary steam for the producer is made in an auxiliary boiler heated by the gases from the producer. It is claimed that by means of this special arrangement for generating steam in a "hot-gas" boiler through the sensible heat of the gases only a small percentage of the total steam required has to come from the independent auxiliary boiler. When the load is light no steam is furnished by the "hot-gas" boiler, but with full load this boiler supplies about 0.7 of all the steam required.

The grate in the gas generator is conical and of the revolving type. The continuous removal of ashes is made possible by a water seal. In the operation of the producer the ash bed is kept about $3\frac{1}{2}$ or 4 feet thick and the fuel bed about 14 feet thick.

One of the special advantages claimed by the manufacturers for this producer is that low-grade fuels containing high percentages of noncombustible matter can be handled successfully. Care must be taken, however, not to use a caking coal.

The following illustration (fig. 1), kindly supplied by Messrs. Crossley Brothers, Manchester, England, shows the principal features of the plant described. The foundations for the new half of the plant are shown in the foreground.

RECOVERY OF BY-PRODUCTS.

Owing to the fact that the wholesale price of sulphate of ammonia in the principal markets is from \$55 to \$60 a ton, the recovery of ammonia as a by-product in the manufacture of producer gas is a very tempting project. The possible financial return seems especially inviting when one realizes that a ton of the ordinary grades of bituminous coal yields when gasified about 90 pounds of sulphate of ammonia. In addition, it is often possible to find a market for the pitch and tar produced.

Anthracite is not suited for any profitable ammonia recovery process, owing to its small percentage of nitrogen and also to its high first cost; but the cheaper grades of bituminous coal, with an average content of about 1.3 per cent nitrogen, are especially adapted to the

successful operation of by-product plants, provided the plants are of sufficient capacity to reduce the operating expenses and fixed charges per unit of output to a reasonable figure. Attempts to recover by-products at plants of small horsepower have not proved successful financially. The impression the writer gathered abroad is that no attempt should be made to recover by-products in plants of less capacity than 4,000 horsepower, although by-product recovery plants of much smaller size are in operation.

MOND-GAS PLANT AT DUDLEY PORT, ENGLAND.

One of the most interesting by-product installations in Europe is the 16,000-horsepower Mond-gas plant at Dudley Port, South

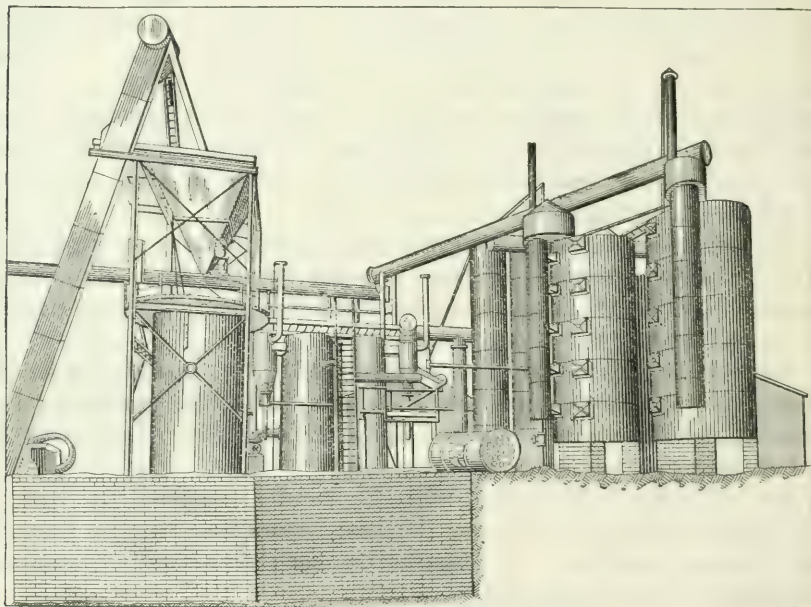


FIGURE 1.—Large gas-producer plant using bituminous coal.

Staffordshire, England. This plant presents so many striking features that the details obtained during a brief inspection are given below:

Number of producers: 8 (2 in reserve).

Make of producers: Mond.

Type of producers: Pressure.

Rated capacity of producers: 2,500 horsepower each.

Number of engines: 2.

Make of engines: Westinghouse.

Type of engines: Vertical, single-acting, 3-cylinder.

Rated capacity of engines: 250 horsepower each.

Hours of operation a day: Twenty-four.

Fuel used: Called slack, but the writer would designate it "run of mine," although it is considerably broken.



A. MOND-GAS PLANT AT DUDLEY PORT, ENGLAND.



B. GAS ENDS OF COMPRESSORS AT MOND PLANT.

The coal was reported to contain 8 to 9 per cent ash and only 1 to 2 per cent sulphur. The writer understands that the coal formerly bought contained from 13 to 23 per cent ash, but because the cost was too high the company operating the plant finally procured a coal mine, and this yields the better grade of coal indicated. The coal is brought to the works by canal boats, as shown in the general view ^a of the plant given in *A*, Plate I.

The machinery necessary for circulating the acid liquor and water, the boilers for generating steam, and the other auxiliaries of the plant are housed in the buildings shown.

Only a small portion of the gas generated is used in the plant itself, because the purpose of the project, aside from the recovery of sulphate of ammonia, is to distribute producer gas to the manufacturing plants in the neighboring towns, which use it for a variety of commercial purposes. The outgoing gas lines are visible at the extreme right in *A*, Plate I. The main distributing line is 3 feet in diameter.

A better idea of the producers is obtained from the view given in Plate II.

The gas is sent into the mains at a pressure of 5 pounds per square inch. The gas ends of the compressing system are shown in *B*, Plate I. At the time of the writer's visit (August, 1908) there were in use 37 miles of gas mains, the longest single run being $6\frac{1}{2}$ miles.

There is, of course, a ready market for the main product of this plant—sulphate of ammonia. The yield amounts to 80 or 90 pounds per ton of coal fired, as previously stated, and the return is approximately \$2.25 for each ton of coal gasified. Each producer when in operation gasifies on an average during a month 20 tons of coal each twenty-four hours.

The tar by-product, which amounts to considerable in a plant of this size, is also sold—some for roofing, some for paving, some for briquetting, and some for use in distilleries.

The steam required by the plant is generated in Climax boilers, which are so arranged that either coal or producer gas or both may be used as fuel.

The gas, after passing the centrifugal tar extractors, is cleaned by means of a sawdust purifier to insure its freedom from tar before it is turned into the mains, as a plug in the mains underground would be serious. That the method of cleaning has proved effective is shown by the following statement made by Mr. Humphrey in a letter received a few months ago: "Since the plant started four years ago the pressure has never been out of the mains and the supply has never failed."

^a Permission to publish the illustrations of the Mond plant was obtained through the courtesy of H. A. Humphrey, consulting engineer, London.

UTILIZATION OF TAR.

In the pressure-producer plants the tar is extracted mechanically and forms a by-product which is usually of little commercial value; consequently, it becomes a nuisance about the premises and must be drained or carted away. At some places attempts are made to burn it, either in furnaces or in the producers themselves, but in general such attempts have not met with favor, save possibly for certain types of down-draft producers.

One method of utilizing the refuse tar in vogue at certain foreign plants is to mix it with the ash and then to spread the mixture in the yards for walks, roads, etc. There is a limit to this use, however, as the entire yard eventually becomes covered to the maximum depth allowable. As already stated, the tar from the plant at Dudley Port is sold to advantage.

At one European plant visited there is special equipment for handling the tar and preparing it for commercial use. The tarry water runs into a large vat or cistern and most of the tar is separated from the water as the mixture passes over a series of screens. The tar with a reduced percentage of water is then drawn off into a large tank fitted in the bottom with pipes for exhaust steam. By means of the steam the tar is kept warm enough to facilitate its being pumped through a pipe line to tank cars on the near-by railroad. The tar as shipped often contains as much as 20 per cent water.

The average weight of water-free tar recovered in this plant is 90 pounds from each ton of fuel fed to the producer. The water-free tar sells for about \$4.25 a ton, a price which yields a return of approximately 19 cents on each ton of coal fired, not taking into account fixed charges and the labor expense of separating the tar. These items, however, amount to little. The tar is used as a binder for fuel briquets and as a basis for various medicines.

PROGRESS IN DESIGN OF SMALL SUCTION PLANTS.

In Europe, the demand for small power plants to use bituminous coal is quite as evident as in this country. The leading manufacturers of gas producers are all working on suction plants for bituminous coal, and each apparently feels that his model is the only successful one. But each manufacturer places special restrictions on the kinds of fuel that may be used. One manufacturer states that the bituminous coal to be used in the suction plant of his design must be of good quality, low in ash (say 8 to 10 per cent as a maximum) and non-caking, and must not contain more than 7 per cent tar. Another manufacturer makes the statement that for other than anthracite coals the users of his producers confine their attention to short-flaming, low-ash fuels that yield little tar and do not cake.



GAS GENERATORS AT MOND PLANT.

PLANT AT A TOWN IN GERMANY.

Although the writer saw several of these suction plants especially designed for bituminous coal, he found only one in actual operation. This was a double-zone plant of 250 horsepower supplying gas to a 150-horsepower horizontal single-acting twin engine. The coal used was reported to contain 25 per cent ash and 2 per cent sulphur. It was claimed that so long as the coal was noncaking such high ash content gave no trouble. In this installation it was imperative that only coals possessing certain qualities should be used. To comply with these limitations it was often necessary to procure three varieties of coal and to mix them in the proper proportion. All fine coal was sifted and the dust was thrown out to prevent matting. With such restrictions imposed it is difficult to see how similar plants can meet commercial demands. All the makes of suction plants for bituminous coal that were inspected were of the double-zone design.

USE OF LOW-GRADE COAL.

The general situation in Europe regarding the use of low-grade bituminous coal is not much unlike the situation here. For the most part the better-grade coals are being used and the poorer grades are being left in the mines. It is true, however, that this condition is recognized abroad as a serious one, and there is deep interest in the possible utilization of low-grade fuels in the gas producer.

In discussing the matter with the writer, one of the best informed producer-gas experts of England expressed the opinion that the proper way of beginning investigations relating to the general development of the field for producer gas was to take up the utilization of low-grade fuels. He said that such utilization was as important in England as in America, and regretted that more active work along this line had not been undertaken in the former country. He also said that plants for low-grade fuels will eventually be perfected by working on a basis different from the present, for he believed many radical departures from the practice of to-day must be made to get the proper solution of the problem.

By careful inquiry the writer was able to learn of only two plants that are endeavoring to use low-grade coal extensively. One of these plants at the time of his visit was still regarded as in the experimental stage, though it had been erected a year before and had given excellent satisfaction for several months. This plant was of the Mond by-product type, with details modified to suit the peculiar requirements of the low-grade high-ash material used as fuel. This material consisted of a mixture of three varieties of refuse, namely, small-size waste material from the principal dump of the mine, large pieces of clay and rock that when broken showed traces of coal, and fine sludge from the coal washery. The first of these materials was

reported to contain between 60 and 70 per cent ash and the others contained smaller percentages, so that the total ash content of the mixture as charged into the producers was between 50 and 55 per cent. A particularly interesting point noted was that large earthy slabs containing almost no coal yielded a high percentage of nitrogen, in many instances far above that obtained from the coal.

Doctor Frank, who is greatly interested in the possibilities of this type of plant, informed the writer that it was possible to recover 80 per cent of the nitrogen in the fuel. From fuel containing 3 per cent nitrogen he believed the yield of sulphate of ammonia might amount to about 140 kilograms per metric ton (1,000 kilograms) of fuel, and that under these conditions the gas for power could be regarded as costing nothing. From the refuse fuel used in the plant under discussion he stated that the yield of sulphate amounted to 20 or more kilograms (44 or more pounds) and the power equivalent of the gas was 500 horsepower-hours per ton of coal fired.

THE JAHNS "RING" PRODUCER.

The other plant for the utilization of low-grade bituminous coal was the Jahns "ring" gas-producer plant at the Von der Heydt royal colliery, near Saarbrücken, Germany. The details of this are so exceedingly interesting that the following brief extracts have been taken from a description published by Mr. Jahns:

Gas producers with a single combustion chamber as hitherto used are generally replenished from time to time with fresh fuel fed in at the top. Consequently the tar content of the gas from such producers varies between low and high.

The "ring" producer is characterized by several combustion chambers placed side by side that can be connected through passages in such manner (the purpose of the producer being to generate gas that contains little or no tar) that the products of distillation have to pass through large quantities of highly incandescent fuel.

A "ring" producer has at least two chambers, large "ring" producers have three or four chambers, and a large producer plant always has several "rings." Figure 2 illustrates the type of "ring" producer in use at the Von der Heydt royal colliery. Four chambers (I, II, III, IV) form one ring of this plant, which consists altogether of five rings.

At the intersection of the partition walls of the four chambers is a vertical flue or channel (*a*, fig. 2). Passages, *b*, from the top and bottom of each chamber lead into this channel; these passages can be opened or closed separately. In the upper part of the passage *a* is a steam injector that increases the suction through the chambers which are in course of preparation—that is, those which were charged last—in order to expel the volatile matter of the coal as quickly as possible and to bring the charge up to the required heat. The steam from this injector is used for producing gas in the gasifying chamber.

The grate consists of separate bars which can be driven out when fuel containing large quantities of slack is used, so that the refuse can drop freely into the ash pit after the producer is burned out. If fuels containing comparatively little slack and low in ash are to be used, a fixed grate which admits of drawing clinker and ashes at any time is put in. The ash pits are closed by plain doors and slides. The hot refuse remains in the ash pit or on the grate until all its available heat has been used to pre-

heat the air supply and to generate additional steam. Afterwards it is removed in ash trucks.

If a plant is to be used for simultaneously producing gas for heating and for power, it has two separate gas mains and gas exhausters.

No charging is done while the chambers are working in the order in which they were ignited. The chambers are suitably connected with each other through the central flue, and the injector draws the steam and the tar-containing gases of the later kindled producers through the previously kindled producers, which are connected to the gas main. At the same time the air supply, mixed with steam and heated by the refuse in the ash pit and on the grate, is sucked into the chambers at the bottom.

According to the scheme outlined above, the process of gas production in the Jahns "ring" producer is divided normally into two stages, as follows:

- (a) Gas expulsion or distillation, which may be called the preparatory stage.
- (b) Gasification.

In the multichamber producer the duration of the preparatory stage is only a fraction of that of the gasification stage. In a "ring" generator, therefore, several chambers may be prepared one after the other during the gasification period of one chamber—

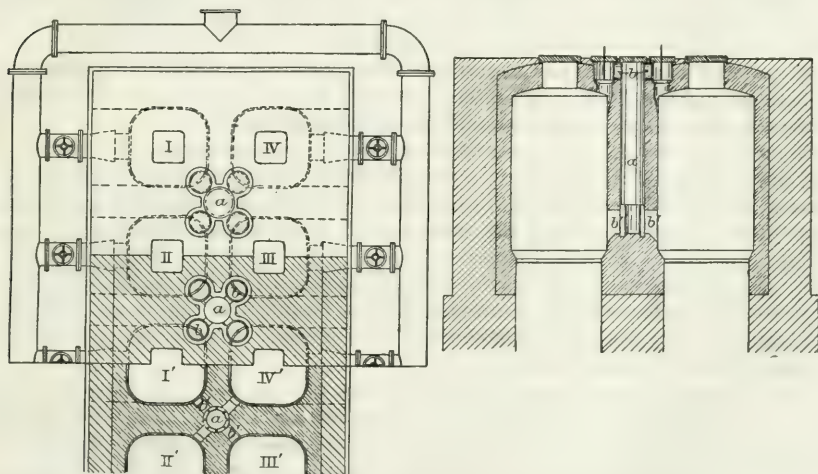


FIGURE 2.—Jahns "ring" producer at the Von der Heydt royal colliery, near Saarbrücken, Germany.

in a three-chamber producer two and in a four-chamber producer three chambers—so that as a rule only one chamber is in preparation when two or three chambers are supplying gas. Therefore, the total working period—that is to say, the combined preparation and gasification time—is the working period of a whole ring, and the capacity of a ring is equal to the capacity of a single chamber multiplied by the number of chambers.

The gases from the chambers in preparation are led into or under the combustion zone of previously kindled chambers, where they are burned or fixed (made permanent) and are drawn off with the gases of these chambers. In the gasification chamber the incandescent fuel decomposes the incoming gases from the preparatory chambers and produces, according to the degree and manner of preparation, gases that are poor in tar and become with advancing gasification still poorer in tar. Nevertheless, the mixture of gases from several chambers remains uniform because the chambers, as they were lighted at different times, are in different stages of gas production.

The power gas contains only such tar vapors as are not volatile at the temperature of the producer, and since they do not decompose in contact with the glowing coal, can be considered as permanent.

If in the course of the process the carbon of the charge in the first chamber is gasified and consumed to such a degree that it can no longer decompose the gases from the preparatory chambers and the steam from the injector, this chamber is shut off from the gas main and its connection to the central channel changed; the steam injector then forces combustion again, the carbon in the charge burns to CO_2 , and the CO_2 formed is decomposed in the other chambers.

This period of complete combustion, or CO_2 formation, is called the "running out" period, and serves to heat the chamber walls to a high temperature for the following preparatory period. At the end of the "running out" period ashes and clinker are dropped into the ash pit; the chamber is then refilled and started as the last chamber of the series.

The emptying and recharging of a chamber take place when it is disconnected from the gas main, and when other chambers are producing gas; gas production is, therefore, neither interfered with nor interrupted. At the same time the steam injector maintains a pressure below atmospheric in the chamber, so that all manipulation can be carried out easily and without danger.

The second chamber to be fired takes up the function of the first one and is treated just as the first was treated; consequently it does not make any difference how many chambers of the ring are connected to the gas main.

The method of operation just described renders possible the direct production from bituminous coal of gas suitable for either heating or power purposes, and not only from pure coals, but also from those containing large amounts of slack.

The power gas is drawn off by means of an exhaustor or a steam injector; the latter may also serve to separate any tar vapors that may be carried over when the producers are not worked with sufficient care. The gas is passed through a scrubber and a sawdust cleaner to purify and dry it and then passes to the gas holder, if one is used, or to the engines. The exceedingly simple cleaning device requires no attention whatsoever. The calorific value of the gas is constantly shown in a very simple manner—that is, by a small test flame from a jet tapping the pipe leading from the cleaner; the general appearance and color of the flame will enable anybody after a brief experience to estimate the heat value of the gas.

At the Von der Heydt royal colliery a generating plant, consisting of five rings each with four chambers, has been in continuous operation since April, 1904. The results obtained there will certainly confirm all that has been said about the suitability and reliability of the "ring" producer. The generators are charged with the refuse separated from the coals. This refuse contains on an average only 20 per cent of good coal and was formerly thrown on the dump.

The charging must be done at about seven-hour intervals, since the average burning time of a chamber with a charge of about 4 tons when producing power gas is about twenty-six to twenty-eight hours. This time is that of a producer with four chambers in the ring. When fuel of better quality is charged the working time of the chamber under similar conditions is shorter. It will be seen that all the attendance required is to inspect the incandescence of the charge and to clean out the clinkers. The whole working of the plant is so simple that unskilled labor may be employed.

The gas obtained is used under steam boilers and in gas engines. One of the latter, giving an output of 60 horsepower, has been at work without a stop since July, 1904, and the other engine, output 175 horsepower, was started in September, 1904, and has been going ever since.

The gas engines are single-acting, four-cycle engines, the larger one of twin type. The 60-horsepower engine drives the electric light generator and also the ventilators for the producer plant; it is running day and night with varying load. The 175-horsepower engine drives a generator producing multiphase current that supplies an

underground pumping plant (for sixteen hours a day) and the machine shop situated about 300 yards away. It also works a transfer table at the colliery station. The two engines have to take a combined load of 120 horsepower for twenty-four hours each day. So far they have run continuously without any trouble or irregularity.

At the time of his visit in 1908 the writer found the producers in full operation, using roofing slabs that upon casual inspection gave little indication of containing any combustible material. It was said that this fuel averaged over 60 per cent ash, a claim which seemed entirely reasonable. The plant was reported to be using over 100 tons a day of this low-grade fuel.

The producer plant had been enlarged and was not only supplying gas to a number of furnaces, but also to a 1,000-horsepower and a 250-horsepower gas engine. A 500-horsepower engine was being added to the equipment. The engines were direct connected to electric generators. The 10,000-volt current was used for driving the local mine machinery and also for furnishing lights in neighboring towns and power for a street railroad.

USE OF BROWN-COAL BRIQUETS.

The lignite, or brown-coal, briquets made in Germany form an excellent producer-gas fuel and are in common use for the small suction plants, generally of the double-zone type, that are put out by various manufacturers. This brown coal closely corresponds to some varieties of American lignite. In Germany the raw brown coal has proved to be undesirable for producer fuel unless in good-sized pieces similar to those of freshly mined Texas lignite. An interesting sight noted at the plant of one of the manufacturers of these producers was a liberal supply of Texas lignite for experimental purposes.

Suction plants burning lignite apparently require as little attention as those using anthracite, and may need less. In certain localities the writer found operators mixing two kinds of brown-coal briquets, as experience had led them to believe such mixing desirable, but the work was simple, and about all the labor required at some of the plants inspected seemed to be the filling of the hopper with fuel.

An excellent idea of the proportions and general details of one of these plants may be had from figure 3.^a

It will be noted that the gas is taken off from about the middle of the vertical shaft of the producer. When the producer is in operation the fire burns from both the top and bottom zones toward the middle. The relative rate of combustion of the two zones is easily regulated. The covers of the charging hoppers are left open to admit the air necessary for combustion, as is readily seen by referring to

^a The illustrations relating to the use of brown-coal briquets and peat were kindly furnished by Gebrüder Koerting, Koertingsdorf, Hamburg, Germany.

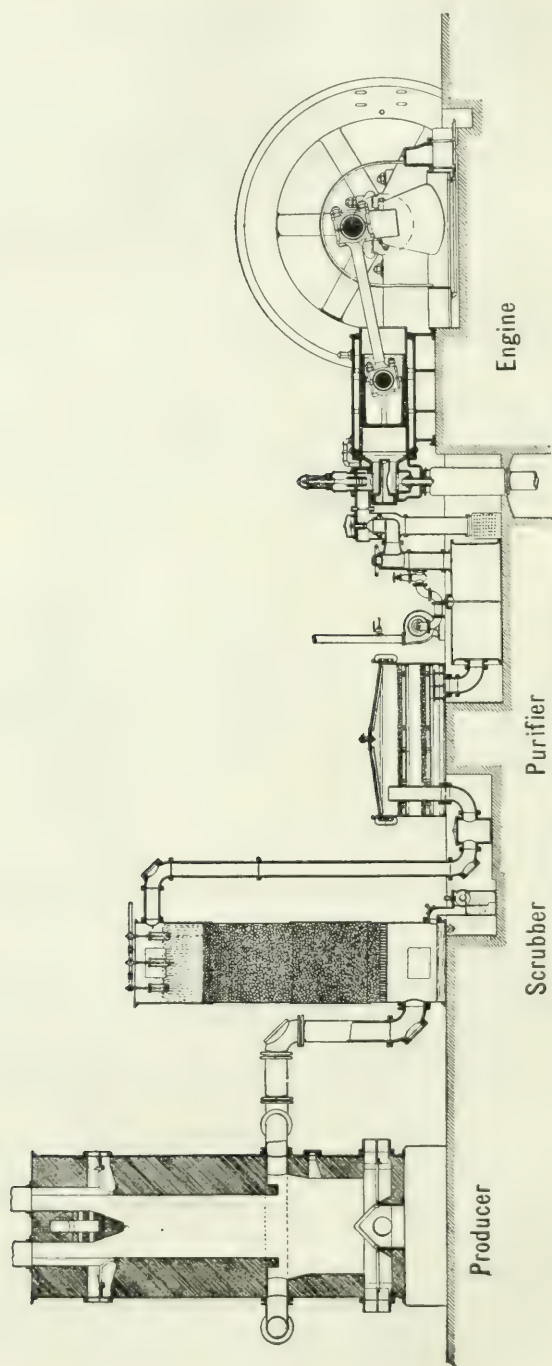


FIGURE 3.—Section of German producer-gas plant burning lignite briquets.

figure 4, which shows the charging floor of one of these plants. Additional air for the lower zone can be readily admitted at the ash pit, as may be seen in the sectional view given in figure 3 or in the view of the main floor of such an installation, figure 5. This type of plant seems exceptionally well adapted to the fuel.

BRIQUET-BURNING GAS PRODUCERS AT FÜRSTENBURG, GERMANY.

An interesting German producer-gas plant using briquets is situated at Fürstenburg on the Oder, about a mile from large brown-coal mines that have been in operation some fifty years. The coal con-

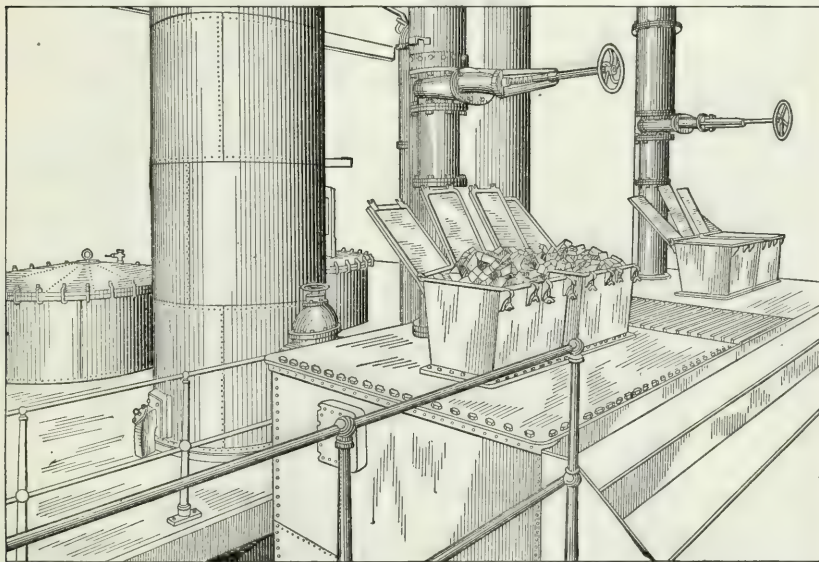


FIGURE 4.—Charging floor of producer plant burning lignite briquets; hoppers open to admit air for combustion.

tains approximately 55 per cent water as it comes from the mine. It is ground, dried until the moisture content is reduced to 11 to 14 per cent, and briquetted without the use of a binder. All the output of the mine is thus utilized. The briquets are delivered continuously from the press to barges lying nearby in a canal. The loading of the barges is done by women, who receive about 30 cents per day.

The briquets are sold chiefly for household use. They have proved of no value for locomotive service, as they fall to pieces when subjected to high temperatures and strong draft and the pieces fly out of the stack. They are not used in large stationary plants because bituminous coal is cheaper. The local producer-gas power plant burning

these briquets comprises the equipment noted below. The power is utilized as indicated:

Number of producers: 2.

Make of producers: Koerting.

Type of producers: Suction.

Rated capacity of producers: 130 horsepower each.

Number of engines: 2.

Make of engines: Koerting.

Type of engines: Single-acting, single-cylinder, 4-cycle, horizontal.

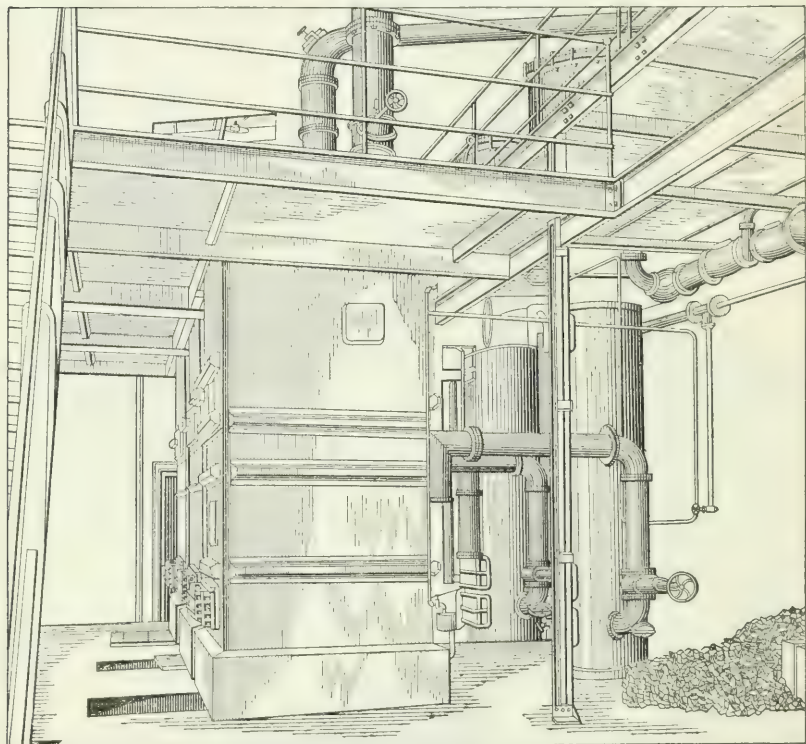


FIGURE 5.—Main floor of plant; doors in ash pit admit air for lower zones.

Rated capacity of engines: 130 horsepower each.

Use of power: Hoisting and other work at the mines, and lighting. (Alternating current, 6,000 volts; transformers at the mine, a mile from the power house.)

Hours of operation: One unit twenty-four hours a day for one week; units used alternately.

The engines for this plant are shown in figure 6.

Although an analysis of the lignite mined near the plant described was not available, the following analysis of a lignite used in producers in Austria may be of interest:

Analysis of an Austrian lignite.

Carbon.....	54.56	Moisture.....	22.26
Hydrogen.....	3.97	Ash.....	3.36
Oxygen.....	15.15	Sulphur.....	1.36
Nitrogen.....	.70	Calorific value	4,900 calories..

USE OF PEAT.

Among the most interesting producer-gas plants in Europe are those utilizing peat as fuel. The peat resources of Europe are extensive and are being rapidly developed. In many countries piles of peat dug for household use may be seen from the railroad trains. In some countries this fuel has thus far been used entirely for domestic purposes, but in others peat forms the main fuel supply for power and manufacturing plants.

The bogs of Ireland have for generations supplied peat for domestic

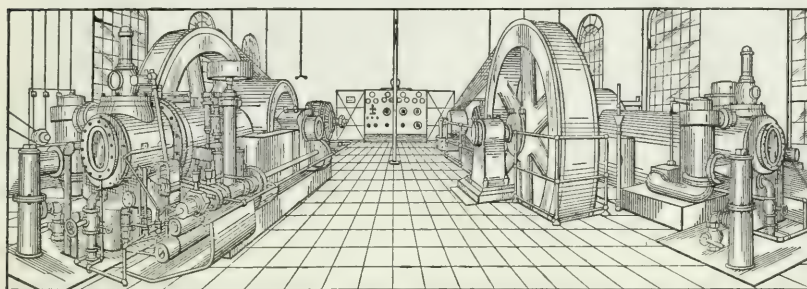


FIGURE 6.—Engines of producer-gas power plant at Fürstenberg, Germany.

fires, but, although the bogs are extensive, the peat has not been used much for generating power. In 1908, however, projects were being considered that involve the erection of extensive power plants in the bogs of central Ireland and the transmission of electric current to Dublin.

Peat has been most largely used in Holland, Austria, Germany, Denmark, Norway, Sweden, Finland, and Russia. In Holland peat has been used for hundreds of years and the bogs have yielded large returns. By the methods pursued, not only is the peat utilized but the bog is left in excellent condition for agriculture.

In Austria and Germany much progress has been made in utilizing peat, especially in the manufacture of peat coke and the making of sulphate of ammonia from peat by means of by-product recovery plants. Doctors Frank and Caro have done much to advance ammonia recovery by their process of gasifying peat in a mixture of air and superheated steam. They find it possible to gasify peat containing 50 to 55 per cent water, thus saving much of the time usually required

for drying. Although much of the peat thus far used in these by-product plants contains only about 1 per cent nitrogen, the returns have been surprisingly good, 40 or more pounds of sulphate of ammonia being obtained from each ton of peat fired.

Doctors Frank and Caro state that from an English peat they obtained 118 pounds of sulphate of ammonia per ton of water-free peat. The gas from each ton of fuel generated all the steam required by the plant and produced power equivalent to 480 horsepower-hours.

Doctor Frank believes that the process will pay with peat containing only 1 per cent nitrogen. The peats of the United States contain a much larger amount of nitrogen than those of Europe, and Doctor Frank is confident that this process, if applied to them, will prove very profitable.

Messrs. Crossley Brothers report that at their works they recovered 134 pounds of sulphate of ammonia from a ton of chemically dry peat containing 2.24 per cent nitrogen. They also report that 1,000 horsepower-hours could be obtained from the gas from each ton of dry peat.

Since the supply of bituminous coal or lignite is large in some countries, the necessity for utilizing the peat resources is not so great in them as in Norway, Sweden, Denmark, and Finland. A recent report shows that Russia leads in the production of peat for generating power, the quantity dug reaching 4,000,000 or 5,000,000 tons a year.

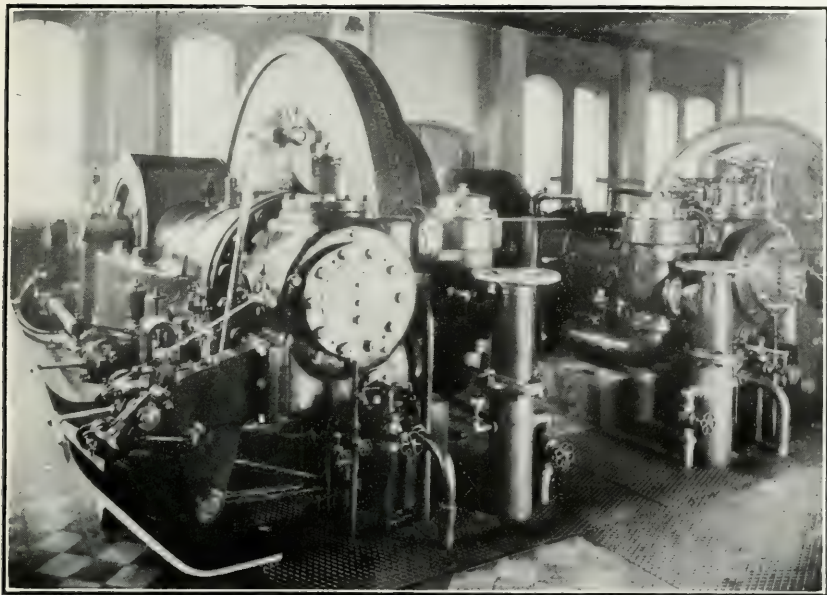
The principal manufacturers of gas producers and producer-gas engines are now putting out double-zone suction producers, designed especially to use peat. These producers burn peat containing 20 to 30 per cent moisture, and seem to work easily and give a rich, clean gas. Figure 7 shows a section of a peat-burning gas-producer outfit that is meeting with general success on the Continent.

These small peat-burning producer plants for generating power are widely used in Europe, although the first plant of this type was installed no longer ago than 1904.

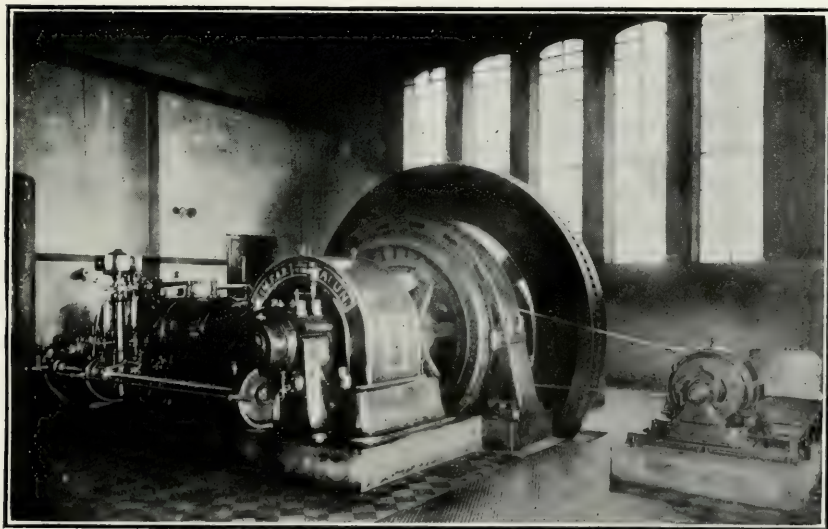
PEAT PRODUCER-GAS PLANT AT SKABERSJÖ, SWEDEN.

The first plant, which stands in the center of a peat bog near Skabersjö, Sweden, is of special interest. Its capacity is only 300 horsepower, and it is situated about 3 miles from the town, to which it supplies the electricity. Half of the plant (150 horsepower) was erected in 1904 and the other half in 1906.

The plant is probably both the first and the smallest producer-gas installation located at a bog and generating high-voltage current for transmission to a point some distance away. In 1908 the plant comprised two suction producers especially designed to burn peat, and rated at 150 horsepower each, and two engines direct connected



A. REAR VIEW OF ENGINES AT SKABERSJÖ, SWEDEN.



B. SIDE VIEW OF ENGINE AT SKABERSJÖ, SWEDEN

to alternating-current three-phase generators, which were running smoothly in parallel at the time of the writer's visit. The 3,000-volt current is transmitted to the town, where it is used during the day for lighting the shops and for driving shop motors and at night for lighting streets and residences. One unit is in operation from 5.30 a. m. to 6 p. m. and the other from 5.30 a. m. to 11 p. m. every day. The charge for residence lighting is 9 cents per kilowatt-hour.

A 35-horsepower peat machine is used for preparing the fuel. This is driven by an electric motor supplied with current from the power plant on the bog. As only 750 tons of dry peat are required per year, there is no attempt to work the plant to its maximum. As there is no difficulty in getting out in the working season, which in this locality is from April 15 to September 1, all the peat needed for a year, only 14 men, local farmers, are employed, and they work as

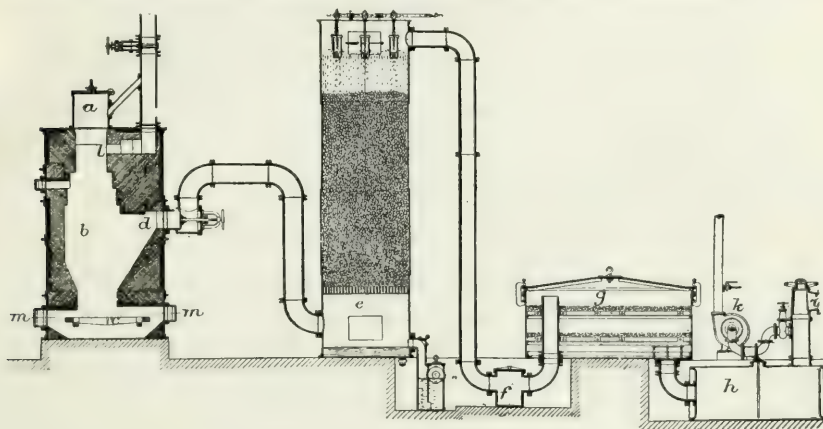


FIGURE 7.—Section of peat producer-gas plant. *a*, *l*, air inlet; *b*, generator chamber; *d*, gas outlet; *m*, air inlets to fire box; *e*, scrubber; *f*, trap; *g*, purifier; *h*, gas collector; *i*, regulator; *k*, aspirator.

little or as much as they please. They receive about 50 cents a day each and get out about 20 tons of peat a day.

Bituminous coal at Skabersjö costs \$3.75 a ton. The dry peat delivered on the platform of the producer plant costs only 80 cents a ton.

The general details of the plant are summarized thus:

Number of producers: 2.

Make of producers: Koerting.

Type of producers: Suction, specially designed for burning peat.

Rated capacity of producers: 150 horsepower each.

Number of engines: 2.

Make of engines: Koerting.

Type of engines: Twin, horizontal, single-acting, 4-cycle.

Rated capacity of engines: 150 horsepower each.

Use of power: Motors in shops and for lighting the shops, streets, and residences at town 3 miles from the plant.

Hours per day: 5.30 a. m. to 6 p. m. for one engine; 5.30 a. m. to 11 p. m. for the other.

Number of men required to operate plant: 3 on day shift (1 for supplying fuel, 1 in the producer room, and 1 in the engine room); 2 at night.

Methods of charging: Charge once an hour.

Kind of fuel and cost: Peat, costing 3 krone (80 cents) a ton at the producer.

Fuel used: 2 kilograms per horsepower-hour.

No fan is used for suction at this plant, the gas being drawn from the producer by the suction strokes of the engines.

The only trouble experienced with the producers has been from the lining, and this has been slight.

It has been found that the plants using this peat operate best with 30 per cent moisture in the fuel; with less the fuel is too dry and steam is required. More than 30 per cent moisture is too much.

The bog is worked by the old type of machine; that is, the peat is shoveled onto the conveyor. The machine is driven by an electric motor, taking current that has passed through a transformer placed on the bog close to the machine.

The average depth of this bog is about 2 meters (6.7 feet), and at the present rate of digging the bog will last about fifty years. It is estimated that 1 cubic meter (1.3 yards) of peat in the bog supplies about 100 to 110 kilograms (220 to 243 pounds) of peat containing 25 to 30 per cent moisture.

The plant was running very smoothly and quietly and required little attention.

The accompanying plate (Pl. III, *A, B*) gives a good idea of the appearance and arrangement of the engines at this plant.

PEAT PRODUCER-GAS PLANT AT VISBY, SWEDEN.

Another peat-burning plant that is attracting the attention of engineers interested in producer-gas development is at a cement works at Visby, Gothland, Sweden. At the time of the writer's visit the capacity of this plant was about to be increased from 250 to 1,500 horsepower. The accompanying plan (Pl. IV) shows the layout of the installation as it stands to-day.

In 1908 the general details of the plant at Visby were as follows:

Number of producers: 1.

Make of producers: Koerting (for peat).

Type of producer: Suction; fan exhausts gas and forces it to engine.

Rated capacity of producer: 250 horsepower.

Number of engines: 1 twin unit.

Make of engine: Koerting.

Type of engine: Horizontal, single-cylinder, single-acting, twin.

Rated capacity of engine: 250 horsepower.

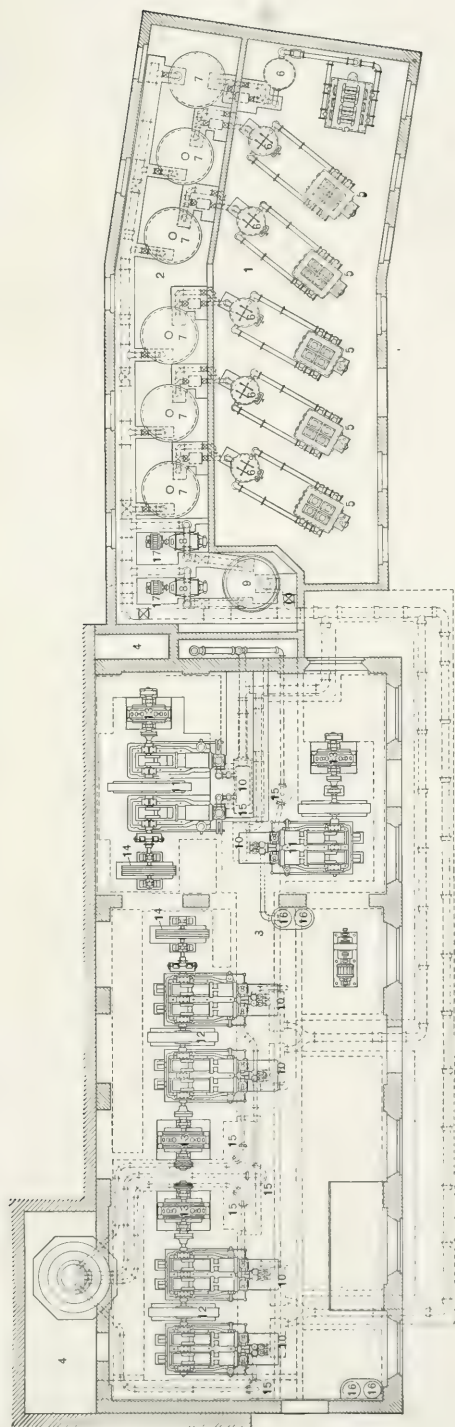
Load carried: Full.

Use of power: Driving machinery in cement works.

Hours of work per day: 10.

Kind of fuel, cost, etc.: Peat, costing, with old methods of collecting, \$1.35 per ton on cars at bog. English anthracite costs nearly \$6 per ton.

The dry peat from the old machine at the bog is more or less broken and varies in size from pieces 12 by 4 by 2 inches to dust. The peat is brought on cars from the bog and dropped into a big concrete storage house, well ventilated by slits in the walls. From this storage house boys take the peat to a crusher, first shaking it out on forks to deposit all small pieces and dust. The crusher



PLAN OF 1,500-HORSEPOWER PRODUCER-GAS PLANT AT CEMENT WORKS, VISBY, SWEDEN.

1. Producer room.
2. Purifier room.
3. Engine room.
4. Air filters.
5. Producers.

6. Scrubbers.
7. Purifiers.
8. Gas aspirators.
9. Gasometer.

10. Expansion chambers.
11. 250-horsepower engines.
12. 500-horsepower engines.
13. Electric generators.

14. Driving wheels.
15. Mufflers.
16. Tanks for compressed air.
17. Electric motors.

breaks it into pieces from 1 to 3 inches in diameter, which are carried by a mechanical conveyer to the bins over the producer.

Boys weigh each wheelbarrow load before dumping it into the crusher. During my stay about the plant (about one and one-half hours) nobody went near the producer. The engines were running nicely and no troubles were apparent. There was serious trouble from tar in the engines when the plant was first started, but this had been overcome.

The dry peat usually contains about 25 per cent of moisture, but at times contains 40 per cent.

PREPARATION OF PEAT AT VISBY.

The working season at Visby is from April 15 to August 8, and all the peat should be dry and in the storage bins by October 1. At the time of the writer's visit hundreds of tons of peat in various stages of drying were scattered over the bog.

The old peat machine, installed in 1902, is of 38 horsepower; that is, the boiler and engine which operate it have about that capacity. The peat is shoveled onto the conveyer, and men with a series of knives cut the strips from the mixer into the required lengths. The peat blocks are irregular in size and always break more or less during drying. Originally 26 men were required for an output of 30 tons of "dry" peat (containing 25 per cent moisture) in a ten-hour day; later the number of men was reduced to 23. The machine cost \$3,375.

The new machine, installed in the spring of 1908, is the first of its type, and when seen was, of course, still somewhat experimental. It is of 42-horsepower capacity, cost \$7,155, and with a crew of 10 men turns out 60 tons of "dry" peat in a ten-hour day. The crew comprises 1 engineer and 1 helper, 1 digger (at the buckets), 4 field-press men, 2 track layers, and 1 trolley man who couples and guides the cars.

With the new machine the peat is dug by a bucket dredge and conveyer, passes through shredding and mixing devices, and runs into the cars as a pasty mass. It is then taken to the drying field, dumped into a frame on the ground, leveled with hoes, rolled and divided into bricks. The longitudinal divisions are made by blades on the roller, the transverse are made by a 3-disk cutter pushed by a man. The bricks measure about 8 or 10 inches long, 4 inches wide, and 2 inches thick and weigh (when containing 25 per cent moisture) 1.75 pounds each.

The average depth of the bog is approximately 6.7 feet, and the output of dry peat is about 370 pounds per cubic yard of peat from the bog.

About thirty days are required for drying—two weeks before piling and two weeks after. The women who pile the peat receive 12.5 cents per 1,000 pieces, and their average wage is 47.5 cents to

54 cents per day. The cables that drag the cars of peat about the field are long and break frequently at the bends made by the car grips. With the old systems of work, horses are used to handle the cars.

To load the peat at the railroad, the small cars are hauled up an incline and dumped into the railroad cars. As the hauling requires the attention of three or four men, it is planned to introduce gas-engine haulage. The fine broken peat is used in the steam boiler and makes an excellent fuel.

USE OF BLAST-FURNACE OR COKE-OVEN GAS.

The writer has made no attempt in this brief discussion of what he saw to touch upon the use of either blast-furnace gas or coke-oven gas in internal-combustion engines. Very large power plants using these fuels are to be found throughout Europe, and the adaptation of such waste gases for generating power seems to be looked upon with favor in the principal manufacturing centers. Progress in this direction has been rapid within the past few years.

PUBLICATIONS ON FUEL TESTING.

The following publications, except those to which a price is affixed, can be obtained free by applying to the Director of the Bureau of Mines, Washington, D. C. The priced publications can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

BULLETIN 261. Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, in St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1905. 172 pp. 10 cents.

PROFESSIONAL PAPER 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. In three parts. 1492 pp., 13 pls. \$1.50.

BULLETIN 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp. 20 cents.

BULLETIN 323. Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., January 1, 1905, to July 31, 1906, by N. W. Lord. 1907. 49 pp. 10 cents.

BULLETIN 325. A study of four hundred sterling tests made at the fuel-testing plant, St. Louis, Mo., 1904, 1905, and 1906, by L. P. Breckenridge. 1907. 196 pp. 20 cents.

BULLETIN 332. Report of the United States fuel-testing plant at St. Louis, Mo., January 1, 1906, to June 30, 1907; J. A. Holmes, in charge. 1908. 299 pp. 25 cents.

BULLETIN 336. Washing and coking tests of coal and cupola tests of coke, by Richard Moldenke, A. W. Belden, and G. R. Delamater. 1908. 76 pp. 10 cents.

BULLETIN 343. Binders for coal briquets, by J. E. Mills. 1908. 56 pp.

BULLETIN 362. Mine sampling and chemical analyses of coals tested at the United States fuel-testing plant, Norfolk, Va., in 1907, by J. S. Burrows. 1908. 23 pp. 5 cents.

BULLETIN 363. Comparative tests of run-of-mine and briquetted coal on locomotives, including torpedo-boat tests and some foreign specifications for briquetted fuel, by W. F. M. Goss. 1908. 57 pp., 4 pls.

BULLETIN 366. Tests of coal and briquets as fuel for house-heating boilers, by D. T. Randall. 1908. 44 pp., 3 pls.

BULLETIN 367. Significance of drafts in steam-boiler practice, by W. T. Ray and Henry Kreisinger. 1909. 61 pp.

BULLETIN 368. Washing and coking tests of coal at Denver, Colo., by A. W. Belden, G. R. Delamater, and J. W. Groves. 1909. 54 pp., 2 pls.

BULLETIN 382. The effect of oxygen in coal, by David White. 1909. 78 pp., 3 pls.

BULLETIN 385. Briquetting tests at the United States fuel-testing plant, Norfolk, Va., 1907-8, by C. L. Wright. 1909. 41 pp., 9 pls.

BULLETIN 392. Commercial deductions from comparisons of gasoline and alcohol tests on internal-combustion engines, by R. M. Strong. 1909. 38 pp.

BULLETIN 393. Incidental problems in gas-producer tests, by R. H. Fernald, C. D. Smith, J. K. Clement, and H. A. Grine. 1909. 29 pp.

BULLETIN 402. The utilization of fuel in locomotive practice, by W. F. M. Goss. 1909. 28 pp.

BULLETIN 403. Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*, by Walter T. Ray and Henry Kreisinger. 1909. 49 pp.

BULLETIN 412. Tests of run-of-mine and briquetted coal in a locomotive boiler, by Walter T. Ray and Henry Kreisinger. 1909. 32 pp.

BULLETIN 416. Recent development of the producer-gas power plant in the United States, by R. H. Fernald. 1909. 82 pp., 2 pls. 15 cents.

BULLETIN 428. The purchase of coal by the Government under specifications, with analyses of coal delivered for the fiscal year 1908-9, by G. S. Pope. 80 pp. 10 cents.

PUBLICATIONS OF THE BUREAU OF MINES.

BULLETIN 1. The volatile matter of coal, by H. C. Porter and F. K. Ovitz. 1910. 56 pp., 1 pl.

BULLETIN 2. North Dakota lignite as a fuel for power-plant boilers, by D. T. Randall and Henry Kreisinger. 1910. 42 pp., 1 pl.

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.



